BULLETIN 203 MAY, 1909

NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

OF THE

COLLEGE OF AGRICULTURE AND MECHANIC ARTS

WEST RALEIGH

CORN WEEVILS AND OTHER GRAIN INSECTS.

N. C. COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

THE NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION,

UNDER THE CONTROL OF THE

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N. C. AGRICULTURAL EXPERIMENT STATION,
WEST RALEIGH, N. C.

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CORN WEEVILS AND OTHER GRAIN INSECTS.

By R. I. Smith, Entomologist.

Like practically all agricultural products, corn and other grains are subject to the attack of numerous destructive insects, some of them commencing their depredations in the ripening grain in the fields, while others abide solely in the barns, storerooms or cribs where the grain is stored. Farmers of North Carolina and, in fact, of all the Southern States, expect a greater or less number of weevils or other insects to be in their granaries each spring, and consider it fortunate when only a few are present. As a general rule, the injury inflicted to the grain is underestimated, and the loss in total weight and feeding value is accepted as an annoying but unavoidable condition.

The actual loss occasioned by insects in whole grain and the various stock foods cannot be accurately estimated; the grain is not only reduced in weight and consequent selling value, but is often rendered wholly unfit for human food and less valuable as food for live stock.

As an example of the extent of the injury caused by grain insects, a consideration of the value of the grain crop will be of interest. The corn crop for North Carolina in 1908 was valued at $39,631,000 and the wheat crop at $6,078,000, a combined total of $45,709,000. Since there are no statistics to show the actual annual injury caused by insects, it may be conservatively estimated at five per cent, which is lower than the actual per cent of damage reported for certain other Southern States in previous years. Five per cent of the total is $2,285,450, an amount representing the possible annual damage by grain insects to corn and wheat crops alone in North Carolina.

The list of really injurious species of insects attacking stored grain, and the principal feed stuffs manufactured therefrom, number twenty and upwards. There are two true weevils and at least one dozen other forms known as beetles in their adult stage, while we find six common and injurious species whose parents are moths. Ten of the most important and conspicuous of this number are described in the pages following. The principal damage to whole grains is caused by the rice or black weevil and the angoumois grain moth or fly weevil, but the others mentioned are frequently present in destructive numbers. In eastern North Carolina the black weevil probably predominates, but in the western section the fly weevil holds first position. In many localities these two species and others of less importance are found working together, sometimes actually occurring in the same kernels of corn.

For the reader who is not familiar with the grain insects, the illustrations (original photographs by the author) and statements concerning the life-history of each will help to show the importance of this subject. It is not always realized how rapidly these insects—the true weevil, for example—may increase in numbers under favorable conditions, nor is it known by all that grain may become infested in the field before harvest. With species that produce only one generation annually, it is not realized how important is the matter of killing them in the larval and pupal stages, an example being the dark meal worm. These and other points given under the discussion of each species in the following pages are necessary for an intelligent understanding of the grain insect problem.

The presence of insects in grains, meals and food stuffs is not easily prevented, nor is it an easy matter to kill them after once gaining a foothold, but certain preventive and remedial measures may be adopted to avoid a portion, at least, of the annual loss. A portion of this bulletin is devoted to the discussion of the best known and most effective control measures. Attention is called especially to the carbon bisulphide fumigation treatment, as this has for many years been principally recommended for destroying grain insects. The writer's recent experiments show conclusively that fumigation with this substance cannot give satisfactory returns when employed under ordinary farm conditions where grain is stored in cribs or rooms that cannot be made sufficiently tight to hold the poisonous fumes long enough to kill weevils.

The purpose of this Bulletin is partly to give farmers a more accurate knowledge of the various grain pests, and to caution them to use preventive measures wherever possible, and partly to explain the limitations in the use of carbon bisulphide for fumigation of infested grain.

THE GRAIN WEEVILS.

The popular name for all insects working in stored grain is weevil; but restricting ourselves to the correct meaning of the term, there are only two true grain weevils. These are the rice weevil and granary weevil, two closely related species, which in the mature stage are small dark-colored beetles possessing a snout or proboscis about one-third as long as the body, and belong among a group of snout beetles that include such familiar forms as strawberry weevils, corn bill-bugs, plum curculio, acorn weevils, and many others. The grain pest known to farmers as the fly weevil, a species fully as destructive as the true weevils, should be placed in a different class, because of the mature form being a small moth which does no damage other than to lay eggs; and the same may be said of all the grain pests that develop

into moths. The remaining grain insects, which are different forms of beetles in the mature stage, do not belong to the group of snout beetles, and are not properly called weevils.

The Rice Weevil (Black Weevil) (*Calandra oryzæ*, Linn).

The name corn weevil or black weevil is usually applied to this species, although its original name is rice weevil, so called because of its being first discovered in that grain. The former names are also applied to a near relative, the granary weevil; hence we should preserve the title rice weevil to make this species distinctive. India is thought to be its native home, but the species may now be found in nearly every grain-producing country of the world, and is particularly abundant in the Southern States, but is less numerous farther North.

a *a* *b* *c* *d*

FIG. 1.—The Rice Weevil or Black Weevil; *a*, full-grown larvæ; *b*, pupa from beneath; *c* and *d*, adults—about five times natural size.

Injury is caused by the adult beetles eating into grain for food and shelter, as well as by the larvæ that feed inside the kernels. Small grains like wheat and rice furnish food for only a single larva in each kernel, but in corn three or four may mature. It has been estimated that one pair will, in the course of a year, produce over 6,000 descendants. The effect on the grain is to reduce the weight materially, and consequently its selling value, and renders the grain unfit for human consumption.

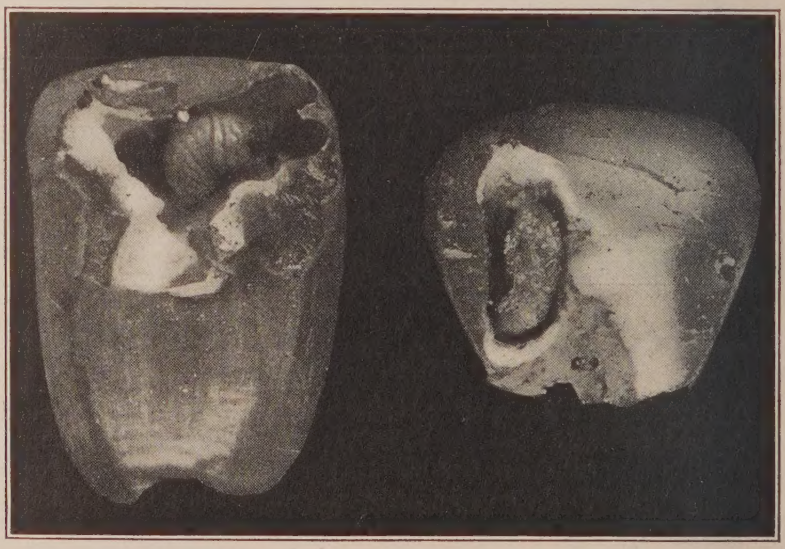
DESCRIPTION AND LIFE-HISTORY.

The mature weevils (Fig. 1, *c* and *d*) average to measure about one-sixth inch, including the snout, which is about one-third the length of the body. The general appearance is dark reddish-brown, but individuals vary from a light brown to nearly black; the thorax presents a network of minute round punctures; the wing covers or first pair of wings bear a more or less distinct red spot near the base and tip of each wing, while the whole surface bears small punctures arranged in longitudinal rows. Underneath these, the second pair of wings are

membraneous and well developed, enabling the beetles to fly to fields remote from the granaries. The snout bears a pair of elbowed antennæ (feelers) and terminates in strong biting jaws.

The larva (Fig. 1, *a*) is white, fleshy and robust, possessing strong, horny, brown jaws. Legs being unnecessary, are not present. When fully grown the larva transforms to a pupa (Fig. 1, *b*) in its burrow, in which stage it shows the general size and outline of the future beetle, but is transparent and white in color.

The eggs are small and white and are laid in minute punctures made in the grain by the jaws of the female weevil. The tiny larva when just hatched commences at once to gnaw toward the center or makes a channel for some distance just under the skin of the grain.



a *b*

FIG. 2.—The Rice Weevil larva and pupa *in situ* in corn; *a*, larva; *b*, pupa; both enlarged five times.

The channel is always filled with a fine powder, quite different in appearance from the pellet-like excrement left by the larvæ of the angoumois grain moth. When nearly grown the larva provides for the easy escape of the mature weevil by leaving only a thin skin over the burrow, and then quietly transforms to a pupa, which in time changes to the mature weevil.

Four or five generations mature each year. At Raleigh the writer observed adult weevils laying eggs on ripening corn in the field, on September 12, 1908; he also found a few small larvæ. From an ear

of corn collected on this date adult weevils emerged on October 17, showing that in this instance the eggs must have been laid early in September, or possibly in August, because it is known that the period from egg to adult is about six weeks in warm weather. In addition to the weevils that fly to the fields and attack the ripening grain, many continue to breed all summer in the granaries where food is obtainable, and whenever infested grain is kept until the new crop is housed, the weevils are furnished ideal conditions for rapid development. It is impossible to prevent grain from becoming infested in the field, but the farmer can see that no weevils are present in the barns or granaries when the crop is housed. The practice of keeping corn the year round and sometimes putting new corn on top of the remains of the previous year's crop cannot be too strongly condemned.

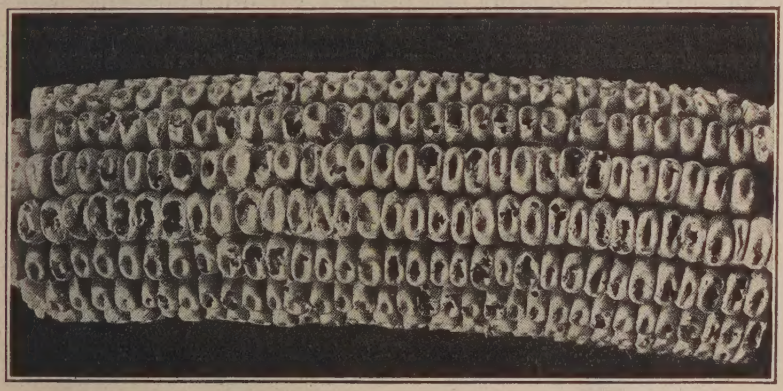


FIG. 3.—Work of Rice Weevils and the Cadelle in two-year-old corn.

Wheat, oats, rice and other grains serve as food for the rice weevil, and may be infested in the field at about the time the kernels are ripening. With corn it has frequently been observed that the ears having a tight husk are seldom attacked by weevils, but we are confronted with the fact that the corn ear-worm (*Alabama argillacea*) frequently makes entrance and exit holes through the husk of the most perfect ears, and by means of these openings the adult weevils enter ears that would otherwise be inaccessible to them.

The general discussion of preventive and remedial measures is given on pages 22 to 27.

THE GRANARY WEEVIL (*Calandra granaria*, Linn).

In general size, appearance and feeding habits the granary weevil is almost identical with the rice weevil. It may be distinguished, however, by its lack of membraneous wings, consequently being unable

to fly, and by the thorax being sparsely and longitudinally punctured. It is also generally somewhat lighter in color than the preceding species. It requires only passing mention here, for the rice weevil far surpasses it in numbers and destructiveness in the Southern States. Owing to its lack of wings, the granary weevil remains in the barn and corn cribs; hence, where proper precautions are taken to feed or remove all infested corn each fall before the new crop is housed, this species can never become abundant like the preceding one. The granary weevil infests wheat, corn, barley and other grains, but is generally considered as a corn weevil.

GRAIN BEETLES AND MEAL WORMS.

There are nearly a dozen species of beetles that attack grain, meal, bran, middlings, and many food products, and often work side by side with the true weevils. The cadelle, which is described, is nearly always found in the barns and grain rooms of the Southern States, and several smaller species of grain beetles are equally abundant, but do less damage because of their small size. The species that the writer has found most abundant are the following:

FIG. 4.—Dark Meal Worm and parent beetle. Two and one-half times natural size.

THE DARK MEAL WORM (*Tenebrio obscurus,* Linn).

This species, illustrated in Fig. 4, feeds mainly in meal, bran and other stock feeds, but may be found at times in whole grains. They often become abundant in grain bins that are not often entirely

emptied, a good illustration having come under the writer's observation recently, in a barn at West Raleigh where hundreds of the beetles were found during the first and second weeks of May.

There is only one generation each year. The beetles normally appear about the last of April, in this section, and soon deposit small, white, bean-shaped eggs in whatever food is at hand. The eggs hatch in two weeks into small delicate larvæ, which increase rapidly in size, and are said to become fully grown in about three months.

The worms, when grown, are darkish brown in color, with a smooth waxy skin, resembling a wireworm. They attain a length of about an inch and live in this stage without much change during the winter, transforming in spring to whitish pupæ and eventually to mature beetles. These are dull black in color and average a little less than three-quarters of an inch in length. The beetles are nocturnal in habits, scampering rapidly out of sight when suddenly exposed by the opening of a grain box.

The meal worms frequently breed in the bottom of grain bins or in corners where meal, flour or other refuse material has accumulated, but as they develop only one generation a year, thorough cleaning-out of all infested material during July or August, after the eggs are laid, will suffice to control them.

The Yellow Meal Worm (*Tenebrio molitor,* Linn).

Differing from the preceding species in color, but not much in size or habits, the yellow meal worm is frequently found in stock foods, flour mills, bakeries, feed rooms and similar places. The worms are yellow, shading to darker toward each end and near the articulation of each joint, but in other respects do not differ from the dark meal worm. The adult beetles of this species are blackish and shining, instead of dull black, and have certain other points of difference, but their habits are the same as the parents of the dark meal worm.

The Cadelle (*Tenebriodes mauritanicus,* Linn).

A widely distributed species occurring in all manner of prepared food products, as well as in grain, meal and other stock foods, is illustrated in Fig. 5. The larvæ was given the name "cadelle" in France many years ago, when it was classed as a meal worm, and in recent years some authorities have claimed that this species is predaceous and carnivorous rather than granivorous, but the writer has observed that it possesses both habits. Chittenden states that he has proved it to be both a feeder on grain and other insects. Consequently the cadelle represents an insect that is both beneficial and injurious. In old corn it is particularly destructive, and in my opinion the injury

caused is greater than its beneficial work by destroying other grain insects. It is not uncommon to find cadelle larvæ feeding in grain from which weevils have emerged.

The parent beetle (Fig. 5) is elongate, flattened, and nearly black, measuring about one-third of an inch in length. The larva (Fig. 5) measures nearly three-fourths of an inch when fully grown, its general coloring being whitish, with the head and anal segments dark brown, and the three thoracic segments marked with brown. The body is fleshy and tapers gradually toward the head.

FIG. 5.—The Cadelle; full-grown larvæ twice natural size; parent beetle seven times natural size.

Both the larva and adult feed in the grain, frequently changing their positions, perhaps in search of weevil larvæ, but most assuredly they cause much injury and should be dealt with like any other grain insect.

Only one generation is produced annually, which is very fortunate, as otherwise the species might prove one of our worst grain insects. Recent experiments by the writer have shown that the beetles are more difficult to kill by fumigation with carbon bisulphide than the adult corn weevil, although the larvæ are quite readily destroyed by this treatment.

THE SAW-TOOTH GRAIN BEETLE (*Silvanus surinamensis*, Linn).

This is one of the smallest, but most common, of the insects attacking grain and nearly all food stuffs. Its small size enables it to penetrate the smallest cracks, and its taste for all kinds of food causes it to be found in granaries, storerooms, groceries, pantries and bakeries, even feeding on red pepper. As a grain pest this species does not actually devour enough to render its presence a source of great loss, but it is nevertheless a great nuisance, and infested food stuffs may be rendered unfit for consumption. Both the larvæ and adults have the habit of eating holes in paper bags in search of food.

The mature beetle (Fig. 6, *b*) is only about one-tenth inch in length, much flattened and chocolate-brown in color. The thorax bears six minute points or teeth on each side, which may be seen in the illustration.

The larva (Fig. 6, *a*) is a slender white worm with darker markings, and is very active, moving frequently from one place to another.

a *b*

FIG. 6.—The Saw-tooth Grain Beetle; *a*, nearly grown larvæ; *b*, parent beetles—both greatly enlarged.

There are said to be six or seven generations annually, the entire life cycle being covered in twenty-four days in midsummer.

The writer's experiments have shown that these beetles are killed by carbon bisulphide fumes a little more easily than are the corn weevils or other grain beetles mentioned above.

GRAIN AND MEAL MOTHS.

We now come to grain insects of which the parents are moths, and among them are found some very destructive species. Only one, the larvæ of the angoumois grain moth, develops entirely in the kernels of grain, either wheat, corn, barley or other cereals, while the remainder have the habit of passing from one grain to another, marking their progress by a silken tube or web, or working their way through meal,

bran or whatever material they occur in, transforming the same into a worthless webby mass. Owing to this habit the meal worms cause damage all out of proportion to the amount of food they actually consume.

In point of importance the angoumois grain moth should stand next to the rice weevil—in some localities, in fact, greatly outstripping it in numbers.

The Angoumois Grain Moth (Fly Weevil) (*Sitotroga cerealella,* Ol.).

The Southern farmer generally applies the term "fly weevil" to this species to distinguish it from the rice or black weevil, but the term is hardly appropriate, because the adult flying moth is simply the parent form of the worm that feeds in the grain. This species does not

Fig. 7.—Showing the work of the Angoumois Grain Moth, as often seen in October—slightly enlarged.

attack meal or food products, but lives in the whole grain, a single kernel of corn often furnishing food for two or three larvæ. The characteristic appearance of an infested ear of corn,. as sometimes found in the field during October or November, is shown in Fig. 7. Fig. 8 shows an ear from which several generations of moths have emerged, such specimens being frequently found in two-year-old corn.

The moths are seen in Fig. 9. the male always being of smaller size. In color they are light grayish-brown, with lines of black, and

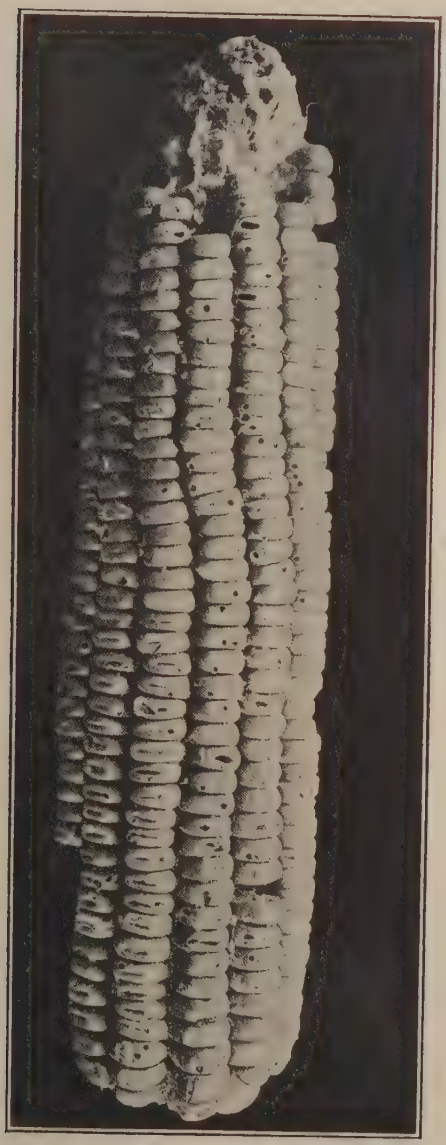


FIG. 8.—Ear of corn from which several generations of the Angoumois Grain Moth have emerged—slightly reduced.

measure across the expanded fore wings a little over one-half inch. The front wings bear a fringe of long hairs on the anal edge, and the hind wings bear a continuous border of the same. The moths are very delicate, easily crushed and readily killed by poisonous fumes.

a *b* *c*

FIG. 9.—The Angoumois Grain Moth; *a*, female; *b*, male; *c*, male with wings expanded—all two and one-half times natural size.

The larva (Fig. 10, *b*) is white, distinctly segmented and attains a length of about one-quarter of an inch. The jaws are brown and horny. When grown the larva transforms to a light-brown pupa (Fig. 10, *c*) in its feeding place, but provides beforehand for the escape of the adult by leaving over its burrow only a thin skin of the grain, through which the moth easily manages to escape.

a *b* *b* *c*

FIG. 10.—The Angoumois Grain Moth; *a*, natural appearance of infested kernel; *b*, larvæ in natural position; *c*, pupa, same—all two and one-half times natural size.

The eggs, deposited singly or in clusters, are at first white, but soon turn reddish and hatch in four to ten days, depending on the temperature. Each female lays from sixty to ninety eggs. The larva when hatched is active and soon penetrates the grain, leaving an almost

invisible opening. In about three weeks the larva is fully grown and transforms to the pupa stage. Both larva and pupa are shown *in situ* in Fig. 10 in partially opening kernels of corn.

During the year five or six generations of moths may be produced. Farmers commonly remark that grain becomes infested in spring when large numbers of moths are seen flying in the granaries—thus gaining for them the name "fly weevil"; but in reality the grain is generally first infested in the field. At West Raleigh the writer found, in 1908, that many moths had matured and escaped from ripening corn in the field on September 10. Two days later an ear of corn was taken and placed in a glass jar, and by September 27 thirty-four moths had emerged. From this it is seen that the first brood in the field must mature here as early as the beginning of September, and it may be that the writer missed the first brood. In any event there must be two full broods and probably three during the summer and fall, the winter being passed in the larval stage. In spring the moths commence to emerge in April, and earlier in the warmer sections of the South, and succeeding generations may mature about every six weeks.

Grain in the field is evidently not infested until nearly grown, or in such condition that the first moths mature about when the grain is ripening. It is certainly a bad practice to leave corn cut and stacked in the field during the fall months, for in such condition more ears are exposed to egg deposition than would be if the corn were stored in the grain cribs. The moths will not be present in the granaries during the fall months if proper precautions have been taken to get rid of all infested grain of the previous year's growth.

The Indian Meal Moth (*Plodia interpunctella,* Hbn.).

This species is not a serious grain pest, but the writer has reared a considerable number of the moths from corn infested principally with the angoumois grain moth. The usual food of the Indian meal moth larva is said to be dried fruit, seeds, nuts, roots and condiments as well as meal and grain products.

The parent moth is shown in Fig. 11. The fore wings expand a little over one-half inch, and may be described as having the inner third dirty whitish-gray, and the outer two-thirds reddish-brown. The hind wings are of a uniform light-gray color bordered with a fringe of hairs. When seen in houses they are frequently mistaken for clothes moths.

The larva or caterpillar reaches a size of about three-eighths of an inch, and unlike the species just mentioned, does not live in a single kernel of grain. On the other hand, they pass from one place to another, spinning large quantities of silk and fastening the particles of food together. It is claimed that they have a special fondness for the

embryo of wheat, one caterpillar often ruining dozens of kernels for seed or food purposes. The entire life cycle may be passed, from egg to adult, in five weeks in warm weather; hence several generations a year may be expected.

FIG. 11.—The Indian Meal Moth, enlarged two and one-half times.

The parent moths are easily killed by poisonous fumes and the larvæ are more easily killed than those of the angoumois grain moth or corn weevil, which live entirely within the grain.

THE MEDITERRANEAN FLOUR MOTH (*Ephestia kuehniella*, Zell).

As a pest in stored grain this species is of slight importance, but it has no equal in destructiveness in flour mills, and in the absence of its favorite food, such as flour or meal, it will attack grain and flourishes on bran and cereal foods. The writer has bred this species from cotton-seed meal. The history of this insect commenced in 1877, when it was discovered in a flour mill in Germany and later invaded Belgium and Holland. In 1892 it was reported as occurring in mills in Canada and during 1895 in New York and Pennsylvania.

The moth is described as having a wing expanse of a little less than an inch, the fore wings being blackish-gray with transverse black markings, the hind wings being dirty whitish color.

The larval stage is really a caterpillar that reaches a length of one-half inch and is pink in color. Its full growth is attained in about forty days, after which it changes to a reddish-brown pupa in a silken cocoon.

The caterpillars have the habit of spinning silken tubes wherever they travel, feeding from the mouth of the tube, and it is this habit that renders them so injurious. Infested flour or meal becomes matted together and lumpy, clogging the machinery in mills and rendering the material in which they feed unfit for human consumption. When such infested material is discovered it should be destroyed immediately, and wherever mills are found infested, prompt measures

should be taken to exclude the pest by destruction of the insects in infested material, by thorough cleaning and by fumigation. Afterward, a strict inspection and quarantine should be established to prevent the entrance of infested material. Farmers need not fear this pest, but millers should be on the lookout for its appearance.

The Meal Snout Moth (*Pyralis farinalis*, Linn).

This is a larger and in many respects more conspicuous species than the ones already described. The writer's attention was attracted to this insect in March, 1909, by finding hundreds of the worms and pupæ in grain bins in one of the Experiment Station buildings. These bins had been in use for a number of years, and it seems that they have not often been entirely emptied, and it is just that condition,

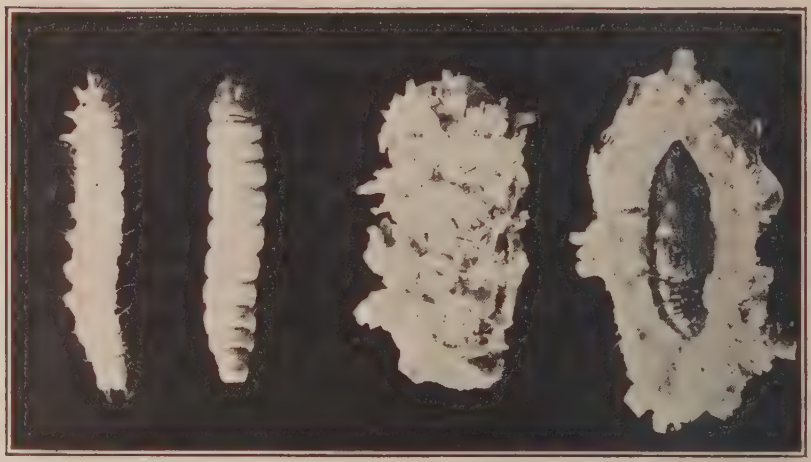
Fig. 12.—The Meal Snout Moth, enlarged two and one-fourth times.

where the bottom of grain bins are never reached, that induces the rapid increase of all kinds of meal worms. The infestation thus found furnished good material for a fumigation experiment, which will be mentioned, and for securing specimens in all stages.

The parent moths are illustrated in Fig. 12 nearly two and one-half times natural size. They measured across the expanded wings from seven-eighths to one and one-eighth inches, and are considerably larger than described by most writers. The females are always larger than the males. The coloring is light or dark brown with reddish reflections, and the wings are crossed by wavy white lines. The moths are nocturnal in their habits and fly quickly when disturbed.

The caterpillars are rather slender and average to measure one inch in length; the head is shiny brown; the first thoracic segment and the anal segments are distinctly orange-yellow in color. In Fig. 13, *a*, is shown its general appearance. Its feeding habits are somewhat like

the preceding species, a delicate silken tube being spun as it feeds. The feeding tube (Fig. 14) taken from a bin of bran, and showing the



a *a* *b* *c*

FIG. 13.—The Meal Snout Moth; *a*, larvæ; *b*, cocoon; *c*, pupa in an opened cocoon—all two and one-fourth times natural size.

adhering particles, is constructed out of sticky, silken threads which are always covered with whatever food the worms are working in, whether it be meal, bran, whole wheat or other grain.

FIG. 14.—Feeding Tube made in bran by the larva of the Meal Snout Moth—slightly reduced.

The pupa stage is assumed in a tough silken cocoon covered with particles of food, as illustrated at Fig. 13, *b*, an open cocoon being

shown at *c*. The pupa is light reddish-brown and of the form illustrated. Fig. 15 shows a small section of a bran bin covered with meal-worm cocoons, which were equally numerous on all sides.

Concerning the life-history, this species passes the cold months in the larval stage, and at West Raleigh the first moths emerged this year on April 20. Three or four generations annually are credited to this insect.

As a grain pest the meal snout moth is not of great importance. Among its various foods may be mentioned hay, straw, seeds, dried plants, all grains and the products made therefrom, and masses of

FIG. 15.—Showing cocoons of the Meal Snout Moth on the side of a grain bin in which bran was kept.

refuse vegetable matter, such as potatoes. Evidently this insect flourishes best in moist surroundings and is not liable to thrive in material stored in a dry, clean place.

As remedial measures the destruction of infested material and cleaning-out of places where the worms are discovered are by far the best. Fumigation with carbon bisulphide might be effective against the caterpillars in a perfectly tight box or bin, but it is doubtful if the pupa in their cocoons can be killed by any ordinary strength. In the bran bin in which the worms were discovered (see Fig. 15), as already mentioned, carbon bisulphide was used this year at the rate

of five, ten, fifteen and twenty pounds, respectively, per thousand cubic feet, on April 7, 10, 14, and 15, and after the fourth treatment some of the pupæ were alive and have since transformed to moths. This bin was apparently air-tight except for a crack on the hinged edge of the cover. The details of the experiment need not be discussed here, except to explain that the first and second treatments killed only a small per cent of worms, the third killed nearly all, and the fourth would have been considered a perfect treatment had not a few moths issued later.

PARASITES AND PREDACEOUS ENEMIES.

Nature provides in the form of parasites a means for preventing the unlimited increase of nearly all injurious insects. Even the larval stages of insects in grain are killed frequently by these beneficial parasites, which are small black flies in the adult stage. Two or three species of chalcis flies have been bred from the larvæ of corn weevils and the angoumois grain moth. The other grain moths and meal worms are known to have parasitic enemies whose work in the aggregate is a considerable help toward controlling grain insects. It is not uncommon to find larvæ and pupæ of the angoumois grain moth that have been killed by parasites. Farmers can easily verify these statements by enclosing some weevil-infested grain in a glass jar and observe the minute black flies that emerge.

Among the predaceous enemies may be mentioned mites, spiders, insects of nocturnal habits, birds and bats.

The mites are diminutive, white, spider-like animals, that prey on many species of grain insects. Spiders occurring in the granaries and mills spin webs that entrap many of the grain moths, while bats hover around the grain bins and barns for the purpose of feeding on the moths. The cadelle, already mentioned, feeds on other grain insects, and probably does considerable good in this respect, but its presence is not desirable, as it also does much injury.

GENERAL CONTROL MEASURES.

These may be either preventive or remedial, or a combination of both, as it might properly be termed, when such measures are taken as tend to kill the adult parent forms, which, in many cases, do no damage aside from laying eggs for another generation. Under the head of preventive measures, several things may be mentioned, but no one alone will solve the problem, and the following discussion is given mainly as a suggestion based on the known habits of these insects. Fumigation with carbon bisulphide has in the past been the chief remedy, and is yet to a certain extent, but the reader is requested to note the results of recent experiments that show how difficult it is to confine the poisonous fumes in ordinary granaries long enough to kill

the various insects that may be present. The old adage "an ounce of prevention is worth a pound of cure" is just as applicable in this connection as it is in troubles of other nature.

PREVENTIVE MEASURES.

Grain first becomes infested through one of two sources: (1) the insects may attack the ripening grain in the field, and (2) the insect may live continuously in barns and granaries ready to commence work in the newly harvested crop. The second source of infestation is more easily prevented than the first.

Field Infestation.—Some species like the rice weevil, angoumois grain moth, saw-tooth grain beetle and a few other small grain beetles are usually found in ripening grain, particularly corn. As a general rule, grain is partially matured, or at least nearly grown, before it is attacked by insects, which of course come from the places in which the grain is stored during the winter. As it cannot be hoped to kill all the insects in stored grains and thus prevent their going to the fields, an effort must be made to prevent them from getting back again in the new grain. Small cereals like wheat and rye should be threshed as soon as dry enough, as that process will kill many of the adult insects and dislodge the eggs. The adult angoumois grain moth is easily crushed and the threshing and handling of the grain destroys many of them. After it is threshed the grain should be stored in tight bins or in sacks, the latter being preferable, because the moths that mature will die without escaping. Whenever the grain, if infested, can be fumigated in practically air-tight boxes or receptacles, carbon bisulphide should be used when the grain is first housed. The practice of storing grain in large bulk is to be commended, as a protection from weevils or grain moths, for then only the surface layers are exposed. This is in direct accord with the recommendation that grain should not be cut and stacked in the field for several months. Such practice tends to allow the insects to infest all the grain more readily than if the same were stored in a large bulk.

Concerning corn particularly, the tight husk offers much protection, and in the field the angoumois grain moth or rice weevil would be excluded almost completely from ears with a husk fitting tightly over the end, were it not for the corn ear-worm, which frequently makes entrance and exit holes, that furnish easy entrance for the grain moths or beetles. However, the presence of the ear-worm is an argument in favor of housing the grain as early as practicable. The longer it is left in the field the greater will be the number of ears infested. Of course, if the farmer does not see that the barns and granaries are free from insects when the grain is stored, the extent of the field infestation is of less importance.

Cleanliness.—The ideal place to store grain is in a special building separated from the barns, but when grain must be stored in the latter place all old infested grain should be used before the new crop is housed, and precautions should be taken to guard against leaving heaps of waste corn, or other material in which the grain insects may be feeding. The writer has known many farmers to place new corn on top of a few bushels of old corn literally being devoured by the weevils and other insects. Farmers will also often boast that their bins or cribs are never emptied. This practice cannot be too strongly condemned.

Storing Corn in the Husk.—It has often been observed that unhusked corn is less liable to weevil injury, and this is true with varie-

FIG. 16.—Two-year-old Corn showing protection from weevils afforded by a tight-fitting husk—about one-half natural size.

ties that have a tight-fitting husk, when not too badly injured by the ear-worm. In Fig. 16 is shown an ear of corn two years old which was taken from the same lot as the one shown in Fig. 3. It is seen from this cut how the tightly fitting husk acted as a protection. In the same lot, however, the ears on which the husk was loose were all badly injured. When it is considered that corn is nearly always first infested in the field, the value of storing unhusked corn seems somewhat doubtful.

Moth Traps.—All the grain moths are nocturnal in habits and may be attracted to lights. By placing in the corn cribs wide shallow pans containing a little kerosene, with a lantern suspended just above or set in the middle, hundreds of moths may be trapped. They will fly to the light and fall into the pan, and even if they escape again the

kerosene will kill them. These traps may be used in the spring when the angoumois grain moth commences to emerge, or at any other time when they are abundant.

Repellents.—Various substances have been tried for sprinkling over grain in storage to repel the parent insects, but few are of practical value. Salt, air-slaked lime or powdered sulphur are said to be employed with some success. Naphthalene flakes act as a powerful repellent, but its use is objectionable, and the same is more or less true of the other substances named.

FUMIGATION TREATMENT.

The destruction of insects in stored grains or cereal products, by poisonous fumes, has been recommended by so many writers that many people have come to the conclusion that the treatment must be perfectly reliable; but experience would teach otherwise. Carbon bisulphide is the chief dependence, but other substances, such as benzine, naphtha, carbon tetrachloride, burning sulphur fumes and hydrocyanic acid gas, have been suggested. The last named is a deadly poison, and if used for fumigating in a perfectly air-tight space would be certain death to all grain insects. It is too dangerous, however, to be recommended for general use.

Sulphur Fumes.—The fumes of burning sulphur, chemically known as sulphur dioxide, have long been known as a powerful fumigant and disinfectant, and have been used successfully for destroying rats and other animals. For several years it has been recognized that sulphur fumes would kill insects. During the past fifteen months the writer has made many experiments to see if this knowledge could not be made use of in killing grain pests. The results proved conclusively that sulphur fumes will kill grain insects, not only the adult forms, but the larvæ and pupæ of the rice weevil and angoumois grain moth as well; but the germinating power of the grain so treated is destroyed or much weakened. It was found that the fumes produced by burning two and one-half pounds of sulphur either in a moist or dry atmosphere of one thousand cubic feet space, for twenty hours, would kill all exposed adult insects and practically all the young stages in the grain, but that this also destroyed its germinating power. In making these experiments the sulphur was placed in a metal dish, one side of the pile wet with alcohol, which was sufficient to start the sulphur burning by simply applying a match.

While this treatment cannot be recommended for general fumigation, there is no doubt of its being the easiest and cheapest method of fumigating corn cribs, granaries and similar places whenever they are being cleaned out and freed of insects in preparation for the reception of more grain. The amount stated above will kill all insects

if the space is made practically air-tight, but if the fumes escape through cracks the amount necessary for successful fumigation cannot be estimated, and the same statement would be true of any poisonous gas.

Carbon Bisulphide Treatment.—Carbon bisulphide is a heavy, clear, foul-smelling liquid, which evaporates rapidly when exposed in shallow dishes. The vapor is a deadly poison when confined in sufficient quantity, and has been extensively used for killing all kinds of insects in stored grain, cereal products, or other material. The amount required is claimed by excellent authorities to be only one pound in 1,000 cubic feet of space, provided there is no escape of the poisonous vapor for about twenty-four hours. This means ideal fumigating conditions, which cannot be secured under ordinary circumstances. The question therefore becomes, what amount of carbon bisulphide must be used to overcome the loss due to leakage? The writer has recently conducted numerous experiments, all of them showing that the diffusibility of carbon bisulphide fumes is greater than generally supposed, and that fumigation of corn, for instance, in a well made, apparently tight grain bin, may not result in killing weevils unless twenty or more times the usually recommended amount be used.

The vapor of carbon bisulphide is 2.64 times heavier than air, so that it settles rapidly if exposed on the top of grain or whatever is being fumigated. This fact has led many people to suppose that it can be used successfully in any space with air-tight sides and bottom, provided the top is covered to exclude currents of air, and that under these conditions the heavy vapor would not escape. It does, however, diffuse in the same manner as other gases, although not as rapidly as those of less specific gravity, and recent experiments have shown that if there is any chance of leakage from the top, the expected results will not be obtained. Where will we find a farmer's grain box, corn crib, or storeroom that can be made air-tight without prohibitive trouble and expense? Not in North Carolina or any other farming district!

One writer has made the statement that, "one pound of carbon bisulphide poured over one hundred bushels of corn will kill all the insects even in open cribs," and farmers are constantly being advised to fumigate with two or three pounds to one thousand cubic feet of space, in fairly tight rooms.

RESULTS OF EXPERIMENTS.

The adult grain moths are killed by the vapor from a small quantity of carbon bisulphide, but the grain beetles require a much greater strength, and it is even more difficult to kill the young stages, larva and pupa, of the rice weevil and angoumois grain moth, in their bur-

rows. The writer has made numerous experiments with grain insects in all stages, using a practically air-tight fumigating room, one having a padded refrigerator style door and the inside walls covered with asbestos. In this it was found that three pounds of carbon bisulphide to one thousand cubic feet, fumigating for twenty-one hours, killed practically all adult insects, but not over seventy per cent of the larvæ and pupæ of the angoumois grain moth or rice weevil.

For an experiment corresponding to farm conditions a grain box of about forty cubic feet capacity was used; the sides were made of matched boards and the floor of concrete; the top edges were covered with sacks and the hinged cover nailed down on three sides when fumigation commenced. The bin was about one-third full of bran. Carbon bisulphide was used by exposing it in shallow dishes near the cover, tests being made with ten, fifteen and twenty pounds, respectively, to one thousand cubic feet space, for twenty-four to twenty-six hours. Larvæ, pupæ and adults of both rice weevil and angoumois grain moth and adult cadelle beetles were used in each test. It was found that the greatest strength used did not kill all the insects twelve inches below the cover, and the average result was not equal to that obtained by using three pounds for twenty-one hours in the tight fumigating room, already described. In view of these results, the writer is forced to conclude that carbon bisulphide, at any reasonable strength, cannot be successfully used for fumigating grain in ordinary corn cribs, grain boxes or storerooms.

Small quantities of infested grain can be fumigated in absolutely tight boxes or barrels by using about one ounce to three bushels. The top must be rendered air-tight, not simply covered with blankets or canvas. Fumigation should continue for about twenty-four hours.

Caution.—The vapor of carbon bisulphide is inflammable and explosive, hence those who use it must be certain that no lighted lanterns or fire of any kind be brought around where fumigation is being made. Any supply on hand should be kept securely sealed and placed in a ventilated room. As a further precaution it may be marked "Inflammable."

The purchase price is about thirty to thirty-five cents a pound from retail druggists, but as low as eight or ten cents per pound when ordered from the manufacturers, who make a commercial grade especially for fumigating purposes.